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Landing Assault Combat Engagement Model (LACEM) Application Support Package (ASP)

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The capabilities and limitations of LACEM are rooted in its functionality. Consequently, this document describes the model using the modeling taxonomy for warfare simulation, entitled SIMTAX, that was developed during a series of Military Operations Research Society (MORS) workshops in 1986 and 1987. SIMTAX was published by MORS and distributed by the Joint Staff (J8) as part of their 1989 catalog of models.

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PURPOSE

The purpose of this model accreditation review is to provide the decision makers with information enabling them to determine the level of confidence they can place in the portion of the AAAV Supplemental Analysis results that stem from models and simulations.

Prepared for: Ms Nora Slatkin, ASN (RD&A)
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CONTENTS

ILLUSTRATIONS

TABLES

SECTION 1. INTRODUCTION

1.1 Purpose

The purpose of the model Application Support Package (ASP) is to provide information about the Landing Assault Combat Engagement Model (LACEM), should it be used in future studies. Accreditation of a model requires an assessment of the specific application to determine the suitability of the model to the intended purpose. While this ASP was developed in support of an accreditation process, this document isolates the *generic* (as opposed to *application specific*) information about the model. This is so that others who are considering the appropriateness of the model to another application will find this compiled information useful and time saving.

1.2 Scope

The capabilities and limitations of LACEM are all rooted in its functionality. Consequently, this document describes the model using the modeling taxonomy for warfare simulation, entitled SIMTAX, that was developed during a series of Military Operations Research Society (MORS) workshops in 1986 and 1987. SIMTAX was published by MORS and distributed by the Joint Staff (J8) as a part of their 1989 catalog of models.

1.3 Organization

Section 2 describes the corrected 13 October 1994 configuration baseline of LACEM. This is accomplished with a simplified description of LACEM and a brief summary of its development history. The fundamental assumptions and limitations associated with the model are also described. Section 3 describes the model design which includes the entities modeled, interactions among them, and interactions with the environment. A more detailed discussion of the model assumptions is provided, as well as a discussion of the implications of the model design and its limitations. Appendix A contains a detailed list of the characteristics and state variables for each of the LACEM entities. LACEM event names and descriptions are contained in appendix B. The acronyms used in this document are defined in appendix C.

SECTION 2. LACEM CONFIGURATION BASELINE

The LACEM configuration baseline described in this ASP is based on the model source code, annotated with comments, which was made available by BDM Federal Inc., on 13 October 1994 to the Advanced Amphibious Assault Vehicle Supplemental Analysis (AAAV/SA) Accreditation Team. Evaluating the LACEM configuration baseline required a thorough review of the available model documentation. The documentation describes how the model works, how the model was developed, how changes to the model are processed and controlled, and what user support functions are available, if any.

2.1 Model Description

LACEM is a Monte Carlo simulation of an amphibious assault of a defended beach. It is an analysis tool useful for comparing the relative effectiveness of amphibious assault weapon systems, under a set of scenario dependent constraints. While its domain is littoral warfare, it does not explicitly model the environment; neither the sea nor the beach. The geometry of the model starts at a line of departure 4500 meters from the beach and each point in the model is represented by a pair of X-Y coordinates. LACEM is an event-driven, two-sided, asymmetric, many-on-many engagement model. Events are time scheduled and calendar driven, and outcomes are based on random number draws and other stochastic processes.

LACEM builds a list of events, and after simulating the first event, it steps directly to the time of the next event, updating the status of each entity, and the calendar of events, before executing the next event. In this way, a simulation run tracks the progress of each landing craft in the assault as they cycle from their departure point to the planned landing points on the beach, where they drop off their loads and then egress from the beach. Along the route the landing craft are engaged by defending units. Defenders include direct fire weapons, indirect fire (IDF) (artillery), and mines. The model produces attrition rates that can be used in other stochastic models. Figure 2-1 is a pictorial representation of LACEM and some of its key elements. Details on these elements and the simulated interactions are provided in section 3.

The user defines the Landing Craft Unit (LCU) characteristics, such as speed, vulnerability to each threat, load being carried (if any), travel path, and weapons (if any). Paths can be varied from landing craft to landing craft to account for navigational variation and the effects of tide, wind, current, and sea state. LACEM runs the assault forces from the designated Line of Departure (LOD), through the ocean and surf, and onto the beach. If transition changes are required, such as changing from high-water speed to low-water speed, these changes must be described in terms of distances from the high-water mark and in terms of time delays to accomplish the transition.

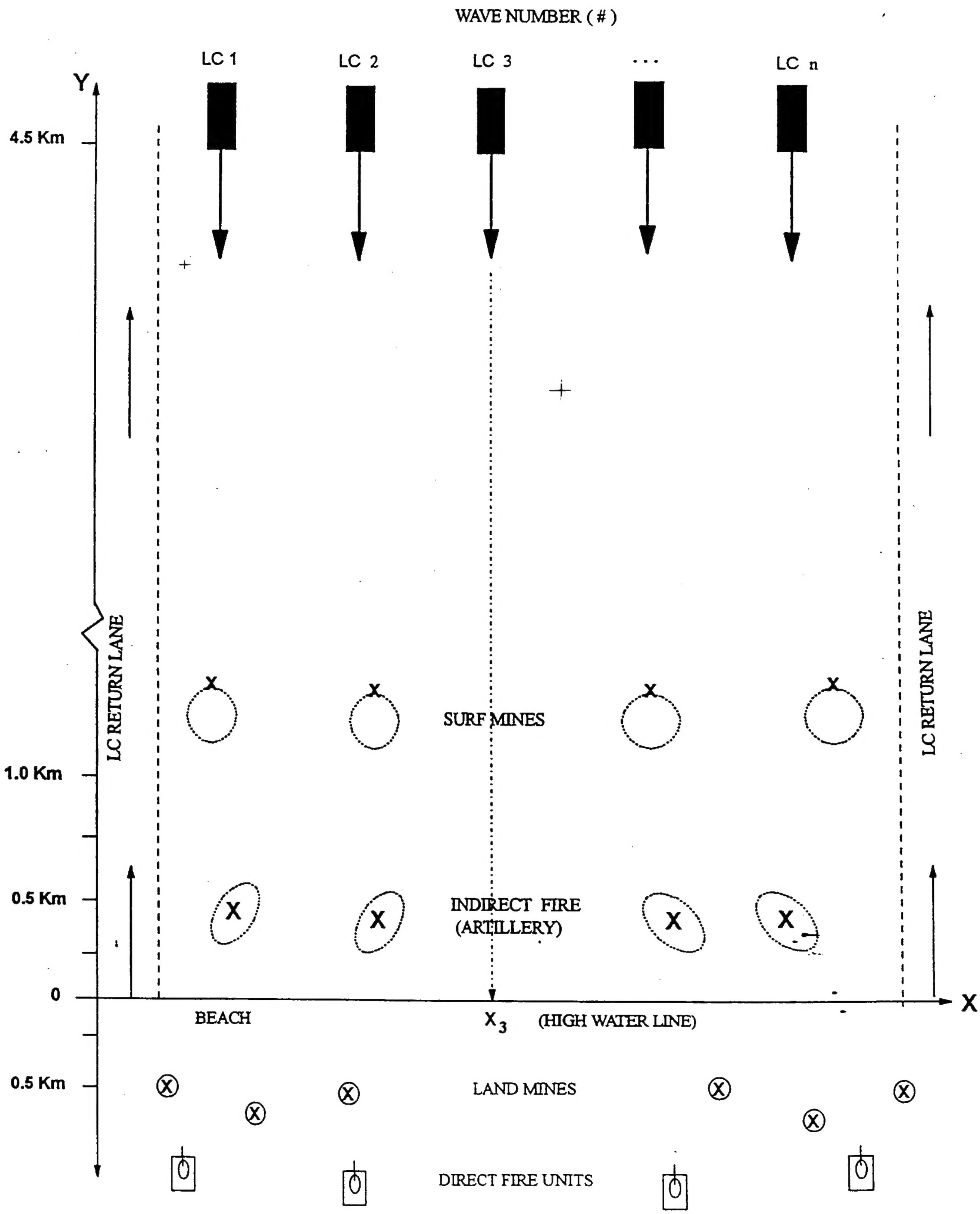

Figure 2-1. LACEM Domain and Scope

The user must provide the characteristics, including a detailed layout of the beach defenders. Rates of fire, probability of kill by range, probability of detection/acquisition, etc., are among the detailed inputs required for the Direct Fire Units (DFUs). For IDF, the Range Error Probable (REP) and Deflection Error Probable (DEP), the radius of damage for each round, and a set of time-dependent aim points must be developed. Mines can be either surf mines or land mines. Surf mines are defined with a radius of activation (or fuzing) and a radius of kill (or radii of probability of kill) with a time delay between activation and explosion. The radius of activation for all mines is a function of the hull type of the landing craft and its footprint on the beach.

Random numbers are drawn for comparison with user-provided probability tables to determine the outcome of acquisition, fuzing, and kill events. For artillery and mine engagements, the Carleton damage function, in conjunction with random number draws, is used to determine the engagement outcome. The model records the successful arrivals over time, by type, as well as a killer/victim scoreboard for subsequent analysis.

LACEM is written in FORTRAN and operates on either IBM PC or VAX computers. A typical Monte Carlo run of 100 repetitions requires 15 to 30 minutes to complete.

2.2 Development History

The LACEM was developed and used by BDM in support of the Ship to Shore Mission Area Analysis (MAA), conducted in 1987 for the United States Marine Corps. The model is well suited to sensitivity analysis, e.g., in the Ship to Shore MAA, three different landing plans, using Amphibious Assault Vehicles (AAVs), Landing Craft Air Cushion (LCAC), and Tank Landing Ships (LSTs) in various combinations, were analyzed. This effort led to the use of LACEM for establishing the mine clearing requirements for the Navy, prior to an amphibious assault.

2.3 Configuration Management and V&V History

All model runs for a specific study are made with a single version of the model. The study version of the model and all input data files are archived and stored for approximately five years. This is done to ensure that additional investigation of study results, if necessary, will be consistent with the initial model runs. This means that the model is closely controlled by Mr. Ed Bitinas of BDM, who is both the software engineer and primary analyst for LACEM. Mr. Bitinas conducted a systematic walk-through of the model's design, operation, and test procedures with the AAAV/SA accreditation team.

BDM uses a standard configuration management procedure that has been applied to LACEM. Changes to any model for a specific study are implemented and tested with oversight (two levels of oversight when practical). Source code changes to LACEM are made only by Mr. Bitinas, after approval by Mr. Mike Ellis (BDM Vice President for Systems Analysis). Changes to the model are documented by comments in the source code.

2.4 Documentation

The only documentation available from BDM was the source code, annotated with comments.

2.5 Fundamental Assumptions and Limitations

LACEM is an input dependent model that requires user decisions on the input data required for a simulation run. This includes detailed plans for the assault and the IDF program. The following are considered the fundamental assumptions of LACEM:

- The environment, which includes terrain features, sea states, weather and other sensor obscurants such as smoke, dust, etc., is not explicitly modeled.
- Entities are treated as point targets. Entity size, acquisition signatures, and footprint (or hull size) are not explicitly played in the model.
- Amphibious assault force supporting arms, e.g., naval gunfire and close air support, are not explicitly modeled.
- The defense command and control functions are not modeled, which means there is no coordinated fire among the beach defenders.
- Withdrawal of the defending DFUs occurs when a sufficient level of assault combat power arrives on the beach. This is defined by the user.

SECTION 3. MODEL DESIGN

The model design is described in several parts. The first part describes the LACEM conceptual logic through the use of the model flow chart. The second part describes the conceptual engine behind the model, i.e., how the entities' actions and interactions are simulated and how the record of the interaction outcomes is maintained. The third part describes the entities being modeled. These are the players in the simulation. Their capabilities to act are defined by general and unique characteristics. The remaining parts of the model consist of descriptions of the input and output data. This section of the LACEM ASP concludes with a listing of the detailed assumptions used in the model.

3.1 Conceptual Logic and Model Flow

The following is a summary of the key events that occur in the LACEM to simulate the surface assault engagements, or interactions. These events and their relationship to one another are graphically depicted in figure 3-1, which describes the LACEM Concept Flow Chart. A description of how the model entities interact is provided in section 3.2. Note that the names for each of the model events are contained and defined in appendix B. In the following discussion of the model interactions, where it is appropriate, the event acronym will be inserted to illustrate how the model functions.

3.2 Conceptual Model - LACEM Interactions

3.2.1 <u>LACEM Engine</u>. The engine of LACEM is simply the scheduling and bookkeeping of the interactions which occur among the entities modeled. LACEM begins by reading user input from the designated data file, creating its internal event calendar, and creating all the model entities (landing craft, defending DFUs, mines, and artillery tubes).

3.2.1.1 <u>Landing Craft</u>. Landing craft are initialized by calculating the time they will enter the simulation by working back from their desired time on the beach to the edge of the model environment (currently 4500 meters). This entry time into the simulation is used by the ENTER event to start the engagements of each landing craft.

3.2.1.2 <u>Defending DFUs</u>. The defending DFUs are created and are set to search for targets. This is done by scheduling an immediate ATACK event, even before landing craft appear as targets. This event will make each defending DFU search for a target, even though they cannot see any landing craft yet.

3.2.1.3 <u>Mines</u>. Mines are placed in the battlefield environment and set to an active status. Mine locations may be either explicitly defined by the user or the model can generate a minefield of random, uniformly distributed mines, within a region specified by the user.

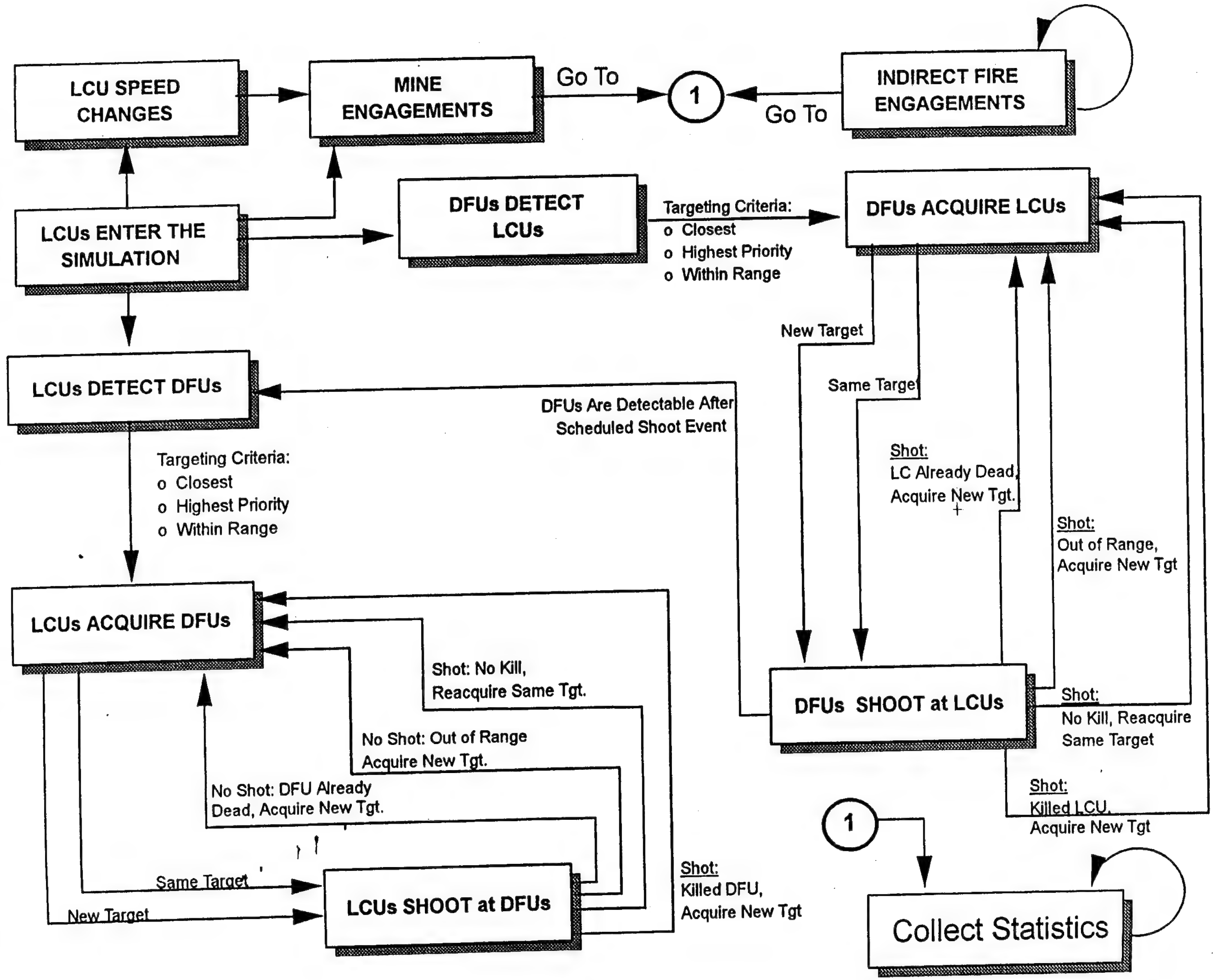

Figure 3-1. LACEM Concept Flow Chart

3.2.1.4 **Artillery Tube**. The impact of the first round for each artillery tube is scheduled with an added delay time, which is a random value, uniformly distributed between zero and the user-provided delay parameter.

3.2.2 **Landing Craft Entering the Simulation**. This event (ENTER) begins the entire direct fire sequence of events that comprise the direct fire battle. The direct fire battle continues until each shooter has no targets; enough assault forces are on the beach, as indicated by the Combat Potential Index (CPI), to cause the defending forces to retreat; defending units have exceeded their prescribed deactivation time; or both sides exhaust their supply of ammunition. Figure 3-2 and table 3-1 illustrate how the direct fire battle is scheduled. The following sections describe the actions occurring within the ENTER event.

3.2.2.1 **Scheduling the Direct Fire Battle**. Each defending DFU schedules the first time it will detect the LCUs. Landing craft detection is constrained by the maximum range of the defender's weapon system, taking into account the distance traveled during the time increment needed to detect the landing craft. Figure 3-2 depicts the maximum range of each of the defending DFUs with a set of curves, marked as DF1 through DF4. The curves intersect the paths of the assaulting landing craft, LC1 - LC3 at different times (minutes from the beach) as shown. This becomes the basis for scheduling the direct fire battle. Table 3-1 shows that DF1 will fire on LC1 19 minutes into its dash to the beach, LC2 will be engaged at 28 minutes and LC3 at 52 minutes, if still alive. Note that DF1 and DF4 open fire on their respective targets at the same time. Then DF3 and DF2 open fire at 23 and 25 minutes, respectively.

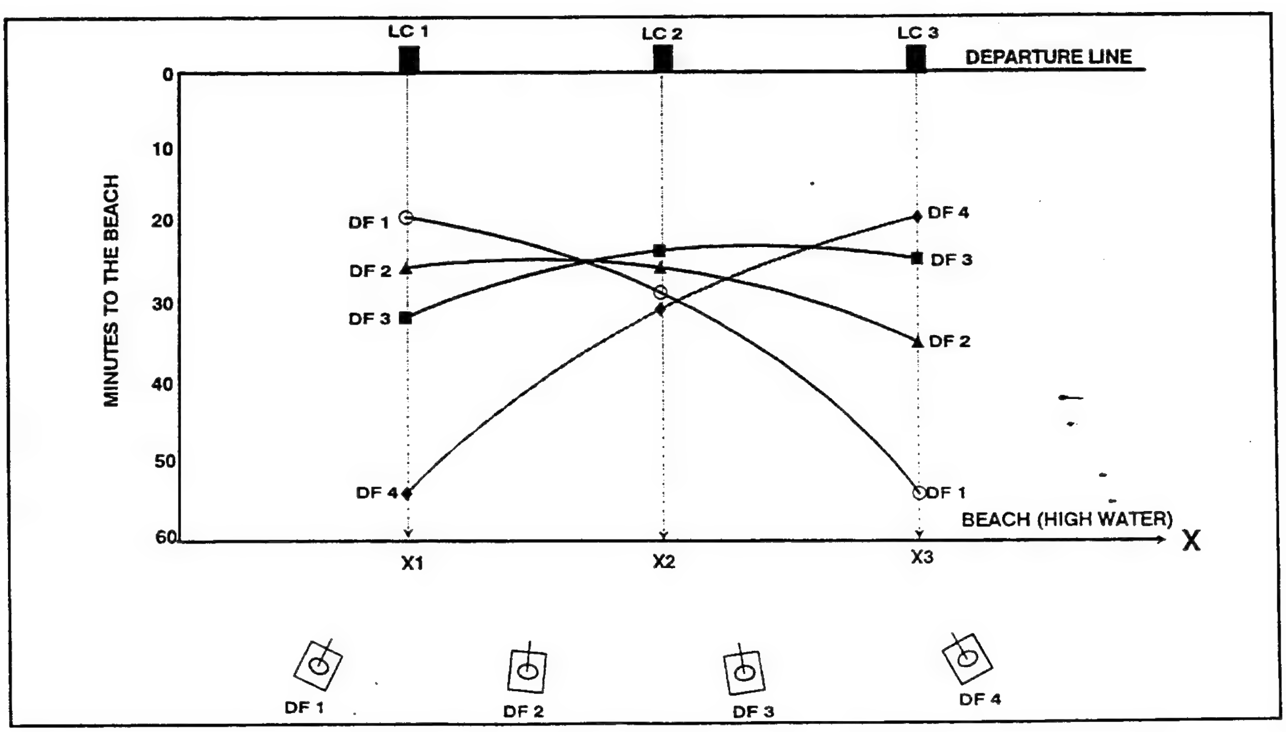

Figure 3-2. DFUs Engagement Diagram

Table 3-1. DFUs Engagement Schedule

DIRECT FIRE UNITS	TARGET LANDING CRAFT			
	LC 1	LC 2	LC 3	. . .
DF1	19	28	52	--
DF2	25	25	34	--
DF3	31	23	24	--
DF4	52	30	19	--
. . .	--	--	--	--

NOTES: 1. Time (in minutes) = Start Time (To) + Lapsed time to engagement.
2. LC travel time to beach ≤ 1 hour.

3.2.2.2 **Detection**. The landing craft schedules the time at which it will detect each defending DFU. This event is constrained by a probability of acquisition curve; by the maximum range of the landing craft's weapon system; and the distance traveled during the time increment needed to detect the DFUs. In addition, an LCU cannot detect a DFU until the time the DFU is scheduled to fire.

3.2.2.3 **Scheduled Detection**. All detections are scheduled in the ENTER event. The only exception to this rule is when a DFU shoots; then every LCU still alive gets a chance to detect the DFU by its muzzle flash. This may be earlier than the initially scheduled detection by an LCU.

3.2.3 **Major Battle Action**. The major action in the simulation is the direct fire battle between the landing craft and the defending DFUs. The battle is initiated by actions described in sections 3.2.1 and 3.2.2. The engagement cycles for DFUs versus LCUs and LCUs versus DFUs are similar in that they include the events of detection, acquisition, and shooting.

3.2.4 **DFUs Versus LCUs**. Once a defending DFU has detected a landing craft (ATKBL event), it schedules an acquisition event (ATACK) with that target. If that target is out of range, or already dead due to some other means, the DFU searches for another target within range with the highest priority (by type). Given a tie in priority, the closest target is selected. With either this new target or the one from the original detection, the shoot event (ENGAG) is scheduled, after an appropriate target acquisition delay. DFUs are assumed to shoot, regardless of target status changes since acquisition. After the shot is taken, and if the target is alive and within range, the damage is assessed. The target is killed if the damage is sufficient, which is determined by a random number draw against the user-provided probability of kill curve. Figure 3-3 depicts a typical probability of kill curve and a random number draw. In all cases a reload time is added and the next acquisition event is scheduled. This process continues until the defending DFU runs out of ammunition

or targets; it deactivates at its prescribed time; the entire defending direct fire force retires; or the simulation replication ends.

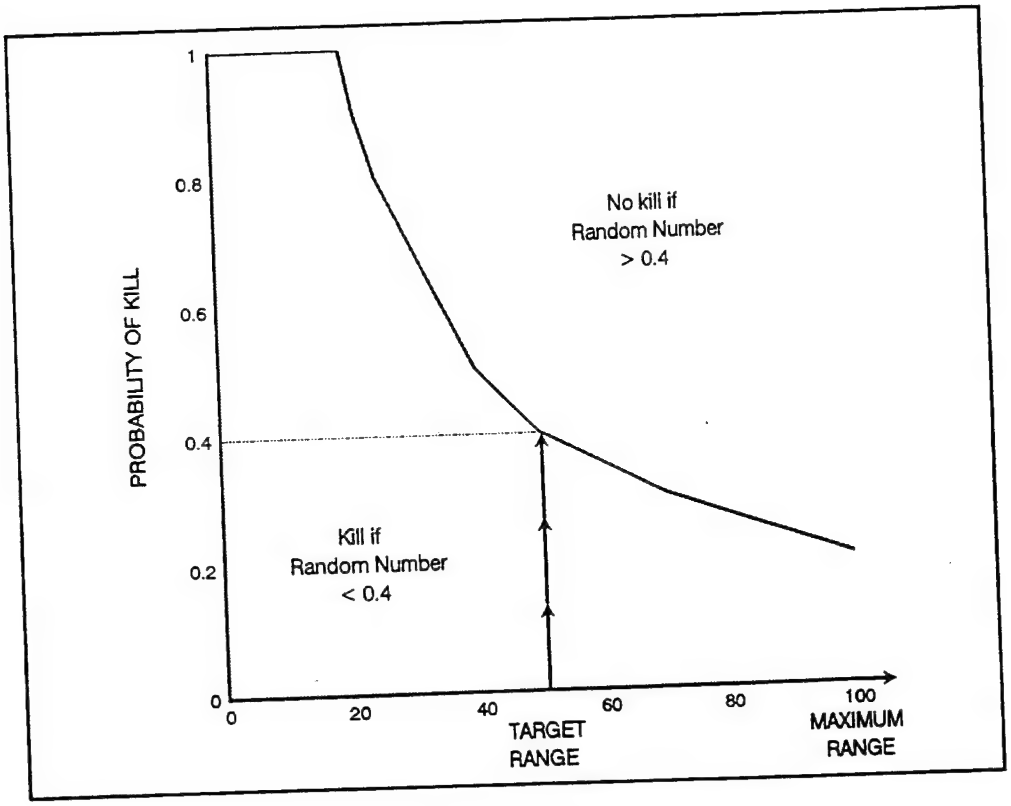

Figure 3-3. Probability of Kill

3.2.5 **LCUs Versus DFUs**. Once a landing craft detects a defending direct fire shooter (SEENM), it schedules an acquisition event (ATENM) for that target. An appropriate acquisition delay is added and a shoot event (SHENM) is scheduled. Note that the LCU cannot shoot until the targeted DFU has already fired, or was permitted to fire, at a target. The shoot event also checks to ensure the target is not dead and is within range. If the target is dead or out of range, a subsequent acquisition event is immediately scheduled, either to wait until the target is within range or to find a new closer target. If the target is alive and within range, then the shoot event takes the shot and assesses the damage to the target. A reload time is then added and another acquisition event is scheduled, either for the same target if it was not a kill, or a new target if it was a kill. This cycle continues until all landing craft have no more targets to engage; have accomplished their delivery missions in the simulation; have run out of ammunition; have all been killed; or the simulation replication ends.

3.2.6 **Artillery Impact Event**. The artillery impact event (INDCT) is initiated at the planned time. Once it has begun, the user-defined artillery program of indirect fire is executed until either all the rounds are fired or the simulation ends. Each artillery tube fires at its aim point, with a prescribed rate of fire, until it runs out of ammunition. The damage is assessed after firing each round. Artillery rounds have no effect on either the

defending DFUs or the defensive mines. Figure 3-4 illustrates how the IDF is modeled, using artillery aimpoints and kill calculations. The artillery aimpoints and firing schedule are provided as inputs to the model by the user. The type of artillery and its location relative to the planned aimpoints are reflected in the DEP and REP values. Once the firing commences, the effects on the landing craft are based on a set of random number draws to determine the detonation, or impact, point of each round. Determining which landing craft (LC) are killed is calculated by a Carleton damage function, which is based on the shell type used.

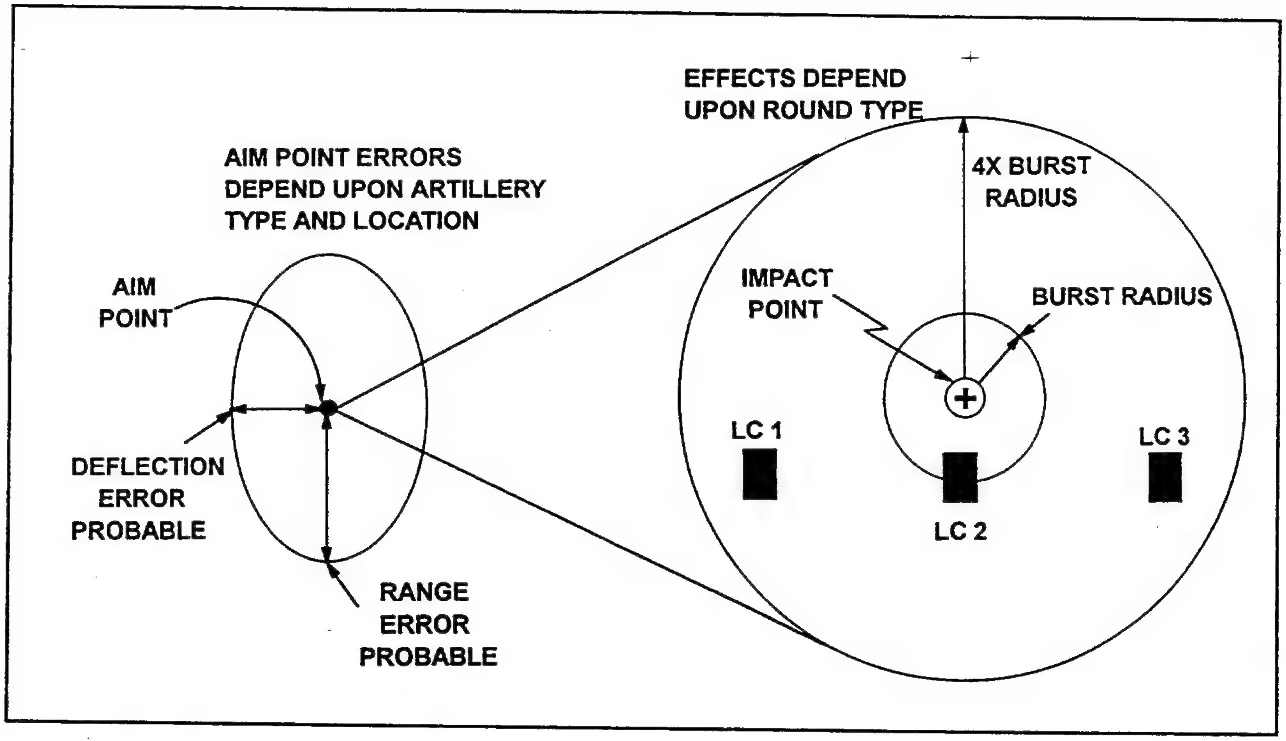

Figure 3-4. Artillery Engagement Simulation

3.2.7 __Mine Event__. The mine event (HITMN) is an absorbing event, in that it does not schedule any other event. Once it is called and it is determined that the mine detonates, each landing craft is independently considered for destruction. Each landing craft is either destroyed or survives, but once detonation has occurred, the mine is dead. Figure 3-5 illustrates the mine engagement concept including mine activation and kill calculations. The landing craft schedules every possible interaction with a mine on its inbound route to its off-load point on the beach.

Note: On the beach after off-load and outbound interactions with mines are considered only in the speed change event.

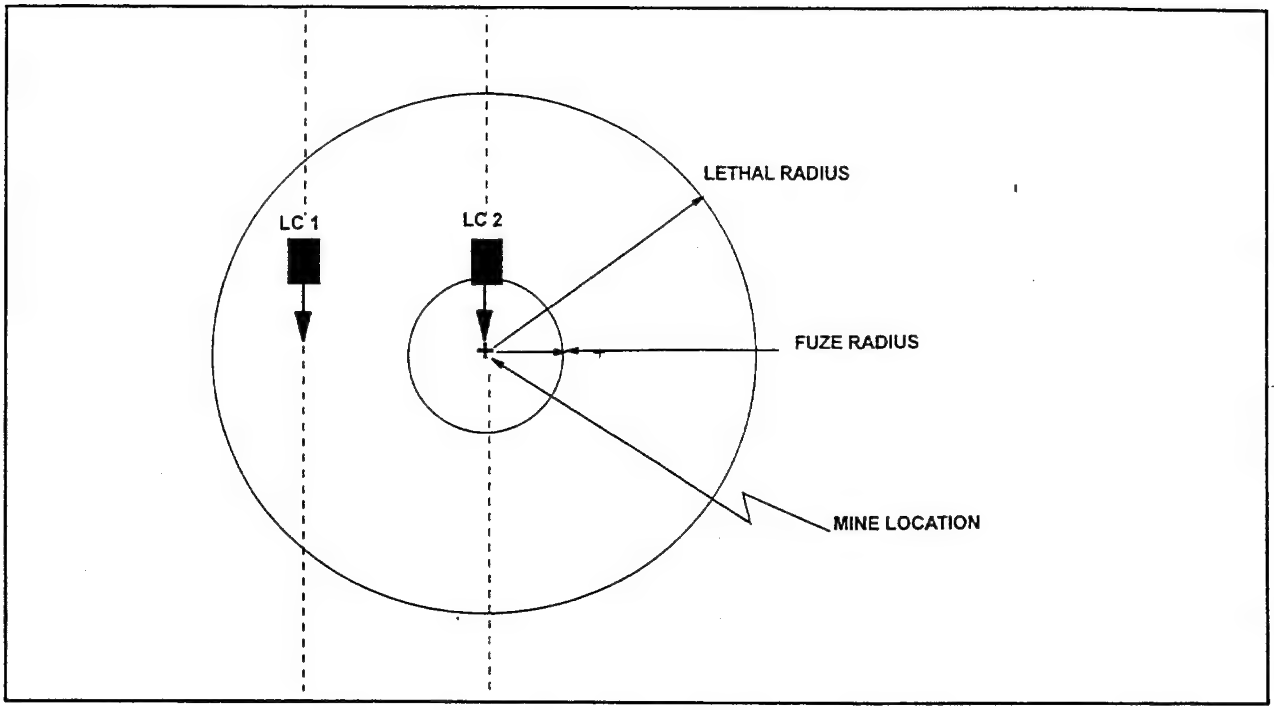

Figure 3-5. Mine Engagement Simulation

3.2.8 <u>Speed Change Event</u>. The landing craft speed changes are scheduled by the speed change event (SPDCHG). It cycles the landing craft through the maneuver states (e.g., inbound fast, slow, and beach speeds, off-loading, and outbound beach, slow, and fast speeds). It also schedules all mine interactions for the landing craft while traversing the beach to the egress lane and while outbound along the egress route.

3.2.9 <u>Summary</u>. Once the simulation begins, the landing craft moves continuously through the simulated environment, which includes the direct fire battle, the artillery IDF program, and the encounters with surf and land mines. During this period, the data collection event (COLCT) collects data at 20 user defined times and the ENDREP event ends the current replication when there are no more events scheduled. ENDREP also collects the necessary scoreboard data, reloads the start conditions of the entities, and restarts the simulation for the next replication.

3.3 <u>Probability Curves and/or Algorithms</u>

LACEM engagement outcomes are determined by drawing random numbers for use with probability curves and/or algorithms.

3.3.1 <u>Probability Curves</u>. Probability curves used in LACEM are usually a function of range, at increments of 250 meters up to 4500 meters. As previously illustrated in figure 3-3, the range between the entities at the engagement event is transformed by the curve to the likelihood of the outcome. If the random number drawn is greater than the likelihood

value of the outcome, then the outcome is not realized in that engagement. The following probability functions are used in LACEM:

- o Probability LCU acquires a DFU is a function of range.
- o Probability LCU kills a DFU is a function of range and random number draw. There is a curve for each DFU type and LCU type
- o Probability DFU kills an LCU is a function of range and random number draw. There is a curve for each LCU speed state and LCU type.
- o Probability of artillery shell detonation point is a function of random number draws to resolve aimpoint range and deflection errors.
- o Probability an artillery shell kills one or more LCUs is a function of the distance between the detonation point and the LCUs, the burst radius of the shell, and a Carleton damage function algorithm, as explained below. LCUs beyond four times (4X) the shell burst radius are unaffected.
- o Probable location of a surf mine is a function of X and Y location errors similar to the artillery detonation point, given the mine field is randomly generated by the model.
- o Probability the mine activates, given an LCU enters the mine activation, or fuze zone, is a function of a random number draw against the probability the mine will detonate.
- o Probability the mine kills one or more LCUs is a function of the number of LCUs within the lethal radius of the mine and a Carleton damage function algorithm explained below.

3.3.2 __LACEM Research for the Artillery and Mine Effectiveness Algorithms__. The following algorithms are used in LACEM to determine a number of event outcomes:

- o The Carleton damage function, D(r), is the probability of killing a target at a given distance "r" from the weapons detonation point. Let R be a random variable representing the lethal radius of the weapon such that any target within R distance from the detonation point will be killed. Then $D(r) = P(R > r)$, where r is the actual distance from the detonation point to the target. The lethal area covered by the weapon lethal radius is πR^2.
- o The Carleton damage function is referenced in the Joint Munitions Effectiveness Manuals (JMEM), Air-to-Surface, Volume FMFM 5-2, page C-2 for point targets that receive damage from fragmentation and blast or just fragmentation. The form shown here is from Notes on Firing Theory, Alan Washburn, 1985, Naval Postgraduate School, Monterey, CA Section 2.3, page 5.

o The Carleton damage function, for some scale factor b, is defined by equation (1). The lethal area of such a weapon is $2\pi b^2$.

$$D(r) = e^{-\frac{1}{2}\frac{r^2}{b^2}} \tag{1}$$

o The function used by BDM in LACEM, where r is the distance from the detonation point to the target and "LR" is the known lethal radius of the weapon, is

$$P_k = e^{-\frac{r^2}{LR^2}} \tag{2}$$

o The Carleton damage function results in a lethal area of $2\pi b^2$ which corresponds to a lethal radius of

$$(\sqrt{2})b \tag{3}$$

o Substituting the value in equation (3) for LR in equation (2) results in equation (1) showing that BDM is using a variation of the Carleton damage function.

o The error function that transforms the range and deflection error probable into random range and deflection error distances for each round of artillery fired and for a random "wiggle" of mine positions is

$$\Delta x = \sqrt{-2.0\ln(U_1)} * \cos(2\pi U_2) * DEP \tag{4}$$

where the U_i's are individually independent and uniformly distributed U(0,1), random numbers and DEP is the deflection error probable.

o The formula for Δx, less the value of DEP, is an approximation of a normally distributed, N(0,1), random variable from Box and Muller (1958) (Reference Law and Kelton, *SIMULATION MODELING AND ANALYSIS*, 2d Edition, page 491). If Δx is distributed normally, $N(0,DEP^2)$, then the linear transformation from N(0,1) to $N(0,DEP^2)$ is accomplished as shown in equation (4). Therefore, Δx is an approximation of a $N(0,DEP^2)$ random variable using the Box-Muller technique. This complies with the JMEM explanation of errors in the accuracy of IDF weapons. It states that all errors in accuracy are assumed to be independent and normally distributed for modeling purposes.

3.4 Entities and Their Characteristics and State Variables

In LACEM, there are four types of entities: amphibious assault landing craft; defending DFUs; defending IDF units; and mines. Each entity is described by sets of characteristics, defining unique attributes and capabilities, which differentiate them from other entities, including those of a similar type. The ability to interact with other entities and the environment is defined by a number of tables, which are often but not always a function of the distance between the entities. In addition, there are sets of state variables that are used to describe the status, including location of the entities at each moment of the simulation run. Appendix A contains a detailed list of these characteristics and state variables for each of the LACEM entities.

3.5 LACEM Input Data

The model requires the following data to conduct a simulation run. Note that the data for the probability of kill and acquisition needs to be a function of range and in 250 meter increments from 0 to 4500 meters. Further note that the landing plan, which needs to be formulated prior to the simulation run, defines the destination on the beach (in x and y coordinates) of each landing craft in each wave of the assault. This plan is used in the simulation to schedule the entry of each LCU in the simulation run.

- Landing craft type and characteristics
- Landing plan data for each landing craft, to include intended destination and time of arrival on the beach, and the CPI delivered to the beach
- Defending DFU type and characteristics
- Defending IDF type and characteristics
- Defending IDF plan
- Mine fields and mine characteristics by type
- Landing craft type probability of acquisition of a defending DFU by type (given the specific DFU has fired or it is passed its scheduled firing time)
- Landing craft type single shot probability of kill of a defending DFU by type
- Defending DFU type target (LCUs) priority list
- Defending DFU type single shot probability of kill of a landing craft type at fast speed
- Defending DFU type single shot probability of kill of a landing craft type at slow speed

- o Defending DFU type single shot probability of kill of a landing craft type at beach speed
- o Effective radius of an artillery type round against each landing craft type
- o Artillery single round probability of kill, given that the target is within the effective radius
- o Acquisition radius by mine type for each landing craft type
- o Probability of acquisition given within acquisition radius for each landing craft type
- o Lethal radius of mine type for each landing craft type
- o Probability of detonation, given acquisition, which is used to represent the percentage of mines cleared in the mine field.

3.6 LACEM Output Data

The outputs from the model are as follows:

- o Number of engagements by defending DFU, IDF, and mine types by landing craft type
- o Number of LCUs killed on ingress to the beach by DFUs, IDF, and mines and by LCU type
- o Number of LCUs killed on the beach by DFUs, IDF, and mines and by LCU type
- o Number of LCUs killed on egress from the beach by DFUs, IDF and mines and by LCU type
- o CPI delivered to the beach as a function of time (over 20 intervals).

3.7 Detailed Assumptions

LACEM makes the following assumptions:

- o Entities are treated as point targets. Entity size, acquisition signatures, and footprint (or hull size) are not explicitly played in the model. It is assumed this is taken into account by the user-provided input data.
- o There is no adjusted artillery fire. The artillery program consists of all single-shot rounds, fired at preplanned aimpoints at a specified rate.

- Artillery does not set off mines and does not kill defending DFUs, i.e., there are no interactions among DFUs, mines, and artillery round detonation.

- Defenses will be cleared when sufficient CPI is ashore. Specifically, once a predefined ratio between defending CPI and assaulting CPI is reached, the defending force is deactivated.

- The defending IDF plan is executed, regardless of the outcome of the direct fire battle. Even if the defending DFUs are deactivated, defending artillery continues to fire its program of fires.

- Assaulting LCUs cannot fire upon the defending artillery.

- The amphibious assault force supporting arms are not modeled explicitly. Any representation of supporting arms effects must be accomplished by manipulating the defending force input data; e.g., a DFU can be deactivated after firing a given number of rounds on the assumption that either naval gunfire or close air support suppresses the DFU.

- An assaulting LCU does not fire upon a DFU until that DFU can fire upon the LCU, i. e., DFUs are given the first shot.

- Once a target is detected or acquired, it remains detected throughout the rest of the simulation.

- Once a landing craft is shot at, the defending DFU will continue to shoot at that LCU until it is dead or out of range, or the DFU is out of ammunition or deactivated.

- There is no coordinated fire among the beach defenders (DFUs and IDF), i.e., there is no centralized Command and Control in the model that alerts the defenders to the presence of the targets and directs weapons to specific targets.

- The probability of acquiring a DFU by an LCU must be a monotonic decreasing function of range at increments of 250 meters, up to 4.5 Km from the beach or the maximum range of the weapon.

- Defending forces will always see the LCUs at the maximum effective range of the DFU weapon type, adjusted by a detection delay time which is a random number draw (see assumption below).

- DFUs shoot each time scheduled, even if the target is already killed by another weapon or just moved out of range. The DFU shoots once at these non-valid targets and then moves on to a different target.

- LCUs have perfect knowledge of its target status, before it shoots, i.e., an LCU does not shoot at dead or out-of-range targets.

- Target detection and acquisition delay times are modelled as a Poisson process with exponentially distributed interarrival times; therefore, all detections/acquisitions are independent. Hence, seeing a target within a formation of targets does not affect the chance or time delay to detect another target in the same formation.

- Minefields cannot be cleared during a model run; therefore, the effectiveness of a mine clearing technique cannot be evaluated on line. However, minefields of different densities can be defined at start time to represent cleared minefields.

APPENDIX A

LACEM ENTITY CHARACTERISTICS AND STATE VARIABLES

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LACEM ENTITY CHARACTERISTICS AND STATE VARIABLES

A1. INTRODUCTION

In LACEM, there are four types of entities: amphibious assault LCUs; defending DFUs; defending IDF units; and mines. This appendix provides a description of each of the model entity characteristics and state variables.

A1.1 Amphibious Assault Landing Craft

The landing craft have characteristics assigned to differentiate the types of landing craft to be evaluated. Each craft has individual characteristics unique to its type. In addition, there is a set of state variables that are used to describe the landing craft status at each moment of the simulation run.

A1.1.1 Differentiating Characteristics. The characteristics that differentiate the types of landing craft are:

- Maximum range of weapon system
- Time required to reload the weapon
- Number of rounds available for the weapon
- Mean time to acquire target that is within range
- Mean time to reacquire same target for the next shot
- Mean time to target a previously seen target.

A1.1.2. Unique Characteristics. The characteristics that are unique to each craft are:

- Landing craft type
- Time landing craft desires to be on the beach
- X coordinate of desired beach position
- Y coordinate of desired beach position

- Time the landing craft enters the simulation (this is calculated by the model, based on the desired on-the-beach time, and speed capabilities of the craft)
- Unloading time of the landing craft
- CPI aboard the landing craft
- Time delay for landing craft speed transitions
- Fast water speed
- Slow water speed
- Beach speed
- Tracking error (landing craft navigation error)
- Exit lane X coordinate for craft that need to move laterally before leaving the beach.

A1.1.3 <u>State Variables</u>. The following characteristics are used by the simulation as state variables to describe the craft status at each moment of the simulation run:

- Current maneuver, i.e., values for ingress fast, transition, slow, beach, egress slow, transition, and fast
- Alive or dead flag
- Current X position
- Current Y position
- Time of last position update
- Current speed
- Craft weapons loading status
- Number of rounds remaining.

A.1.2. Defending DFUs

A1.2.1 **Characteristics**. Defending DFUs are described by the following characteristics:

- o Unit type
- o X coordinate of its position
- o Y coordinate of its position
- o Maximum range of weapon system
- o Reload time of weapon system
- o Number of rounds available
- o Simulation time when unit is no longer active
- o Mean time to acquire target within range
- o Mean time to reacquire same target
- o Mean time to target a previously seen target
- o CPI
- o Time of first shot by unit.

A1.2.2 **State Variables**. The following are used as state variables for the direct fire entities in the simulation:

- o Unit loading status
- o Alive or dead flag.

A1.3 Defending IDF Units

A1.3.1 **Characteristics**. Defending IDF units are described by the following characteristics:

- o Impact time of first shell
- o X coordinate of aim point

- o Y coordinate of aim point
- o REP
- o DEP
- o Shell type
- o Number of rounds to fire at the aim point
- o Separation time between rounds (rate of fire).

A1.4 Mines.

Two sets of characteristics are used to describe mines: type characteristics and the unique position of each mine by type.

A1.4.1 Type Characteristics. Mine types are described by the following characteristics:

- o Mine type wiggle REP
- o Mine type wiggle DEP
- o X minimum coordinate for randomly generated minefield
- o X maximum coordinate for randomly generated minefield
- o Y minimum coordinate for randomly generated minefield
- o Y maximum coordinate for randomly generated minefield
- o Number of randomly generated mines.

A1.4.2 Unique Position of Each Mine by Type. Each individual mine is described by the following characteristics:

- o Mine X position
- o Mine Y position
- o Mine type.

A1.4.3 **<u>State Variables</u>**. The following are state variables used by the simulation to describe each mine at a given moment:

- o Mine status (dead or alive)
- o Actual mine X position
- o Actual mine Y position.

APPENDIX B

LACEM EVENT NAMES AND DESCRIPTIONS

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LACEM EVENT NAMES AND DESCRIPTIONS

The following LACEM event names and descriptions are used in the model code:

(1) ATKBL: Defending DFU detects (sees) an assault landing craft.

(2) ENGAG Defending DFU shoots at landing craft. to include impact results of round. Reload times are added. Every landing craft gets a chance to detect the defending DFU that fires.

(3) ATACK Defending DFU chooses the closest highest priority target (assault landing craft) and acquires the target (aligns sights). Acquisition times are added.

(4) SPDCHG Moves the landing craft through its possible maneuver states.

(5) ATENM Assault landing craft chooses the closest target (defending DFU) and acquires the target (aligns sights). Acquisition times are added.

(6) INDCT Executes the defending artillery fire plan and assesses the results of the impact of each round fired.

(7) COLCT Collects data at 20 user defined times.

(8) HITMN Mine encounters with assault landing craft; determines if the mine detonates, has any effect on all landing craft, and if it kills any landing craft.

(9) ENDREP Ends the current replication. Collects the necessary data, reloads the start conditions of the entities, and restarts the simulation for the next replication.

(10) ENTER The entry of every landing craft into the simulation. All landing craft - mine interactions inbound to the beach are determined, every defending DFU determines the time it will detect the landing craft (if ever), and the landing craft gets the chance to detect every defending DFU. Detection delay times are added.

(11) SEENM Assault landing craft detects (sees) a defending DFU.

(12) - (14) Not used.

(15) SHENM Assault landing craft shoots at a defending DFU if it is within range and alive to include impact results of round. Reload times are added.

APPENDIX C

ACRONYMS

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ACRONYMS

Acronym	Definition
AAAV/SA	Advanced Amphibious Assault Vehicle Supplemental Analysis
AAV	Amphibious Assault Vehicle
ASP	Application Support Package
CPI	Combat Potential Index
DEP	Deflection Error Probable
DFUs	Direct Fire Units
IDF	Indirect Fire
JMEM	Joint Munitions Effectiveness Manuals
LACEM	Landing Assault Combat Engagement Model
LC	Landing Craft
LCAC	Landing Craft Air Cushion
LCUs	Landing Craft Units
LOD	Line of Departure
LSTs	Tank Landing Ships
MAA	Mission Area Analysis
MORS	Military Operations Research Society
REP	Range Error Probable
V&V	Verification and Validation